Measurement of Damping of Advanced Composite Materials for Turbomachinery Applications

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The previous phases of this task have shown that advanced composite materials in general, and specifically fiber reinforced ceramic matrix composites (CMC's), do indeed possess higher damping properties than the baseline metal sample, Inconel 718.

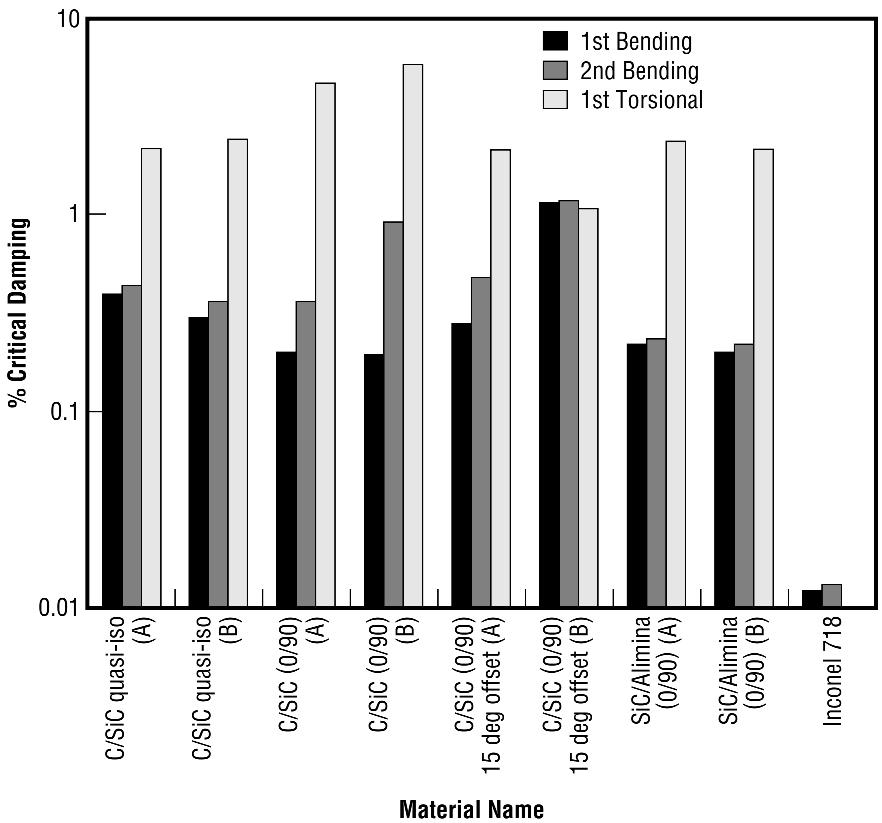

Figure 46.—CDDF/CBLISK beam samples damping results (FY96).

Currently, nickel-based super alloys, like Inconel 718, are used in rocket engine turbomachinery applications. Fiber-reinforced ceramic matrix composites can be used to replace the current selection of metal alloys due to their high-strength, low-weight, high-temperature capability and increased damping capacity. With the increased material damping in CMC's, additional and often complex mechanical dampers will not be needed to allow the component to withstand higher dynamic loading.

This damping study is in its final phase and is tentatively scheduled for completion by June 1997. The study was approved in October 1993. Phases 1, 2 and 2a were completed by the summer of 1996 and consisted of damping tests on many beam specimens.

This task was developed to measure the inherent material damping capacity of composite materials that have promise for use in rocket engine turbine applications. This information can be used in dynamic analysis to predict the dynamic stress of a component under loading.

During this phase of testing, the damping capacities of eight beam samples and two disks of the size used in rocket engine turbines were determined. The beam samples were composed of carbon/silicon carbide (C/SiC) and silicon carbide/alumina (SiC/alumina), where the first term is the fiber and the second is the matrix material. Three fiber architecture's were evaluated, (0/90), (0/90) with 15-degree offset and quasi-isotropic. All three architecture's were represented for the C/SiC material while for the SiC/alumina, only the (0/90) was tested. The two disks, 22.86-cm in diameter, were purchased from Oak Ridge National Laboratory (ORNL) Oak Ridge, Tennessee. The disk samples were composed of silicon carbide/silicon carbide (SiC/SiC) and only differed in fiber architecture, polar woven and cloth lay-up. The polar woven preform was provided by ORNL free of charge. That preform was surplus from an Air Force CMC Disk/Blisk task. The cloth preform was provided at cost as well as the densification and additional handling. The damping capacities for these samples were determined through impact tests conducted at MSFC.

The data obtained from this task can aide in the selection of materials for turbomachinery applications. Turbopump components produced from composite materials will allow the engine to be lighter, thus providing an improved thrust-to-weight ratio. Composites in the turbine area could allow the engine to run at higher tempera-tures which would increase performance. With the addition of higher inherent material damping, additional external mechanical dampers would not be needed, allowing the component to withstand higher dynamic loading and reduce the possibility of failure through high-cycle fatigue. This increased performance equates to larger

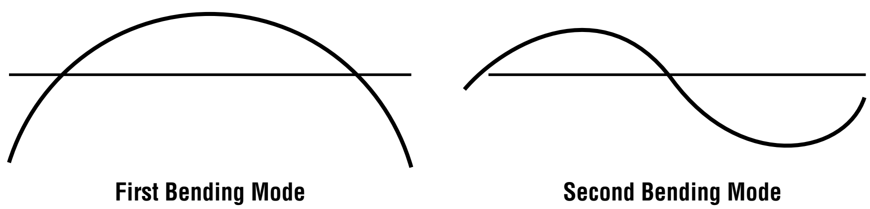

Figure 47.—Beam mode shapes in free-free boundary condition.

payloads or the delivery of smaller payloads to higher orbits.

With the commercialization of space, this data can be utilized by private companies in the development of space vehicles. These vehicles will be lighter, able to perform better and do so at lower development and operations cost.

Composite materials can offer lighter weight, and less costly components to rocket engine applications. The test data from this task has shown that fiber-reinforced composites provide higher material damping than the selected baseline advanced metal alloy. Additionally, with higher damping, composites may increase the life of components subjected to high-vibration environments. The study of the damping properties of advanced composites can aide the engine component designer in the selection of materials for high-vibration environments.

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Biographical Sketch: Donald L. Harris started his career with NASA as a cooperative education student from Tuskegee University in 1986. Harris, upon graduation from Tuskegee in 1990 with a bachelor's degree in aerospace science engineering, accepted a permanent position with NASA/MSFC. He is an aerospace technologist (AST), Structural Dynamics, performing structural dynamic analysis on liquid rocket engine components.

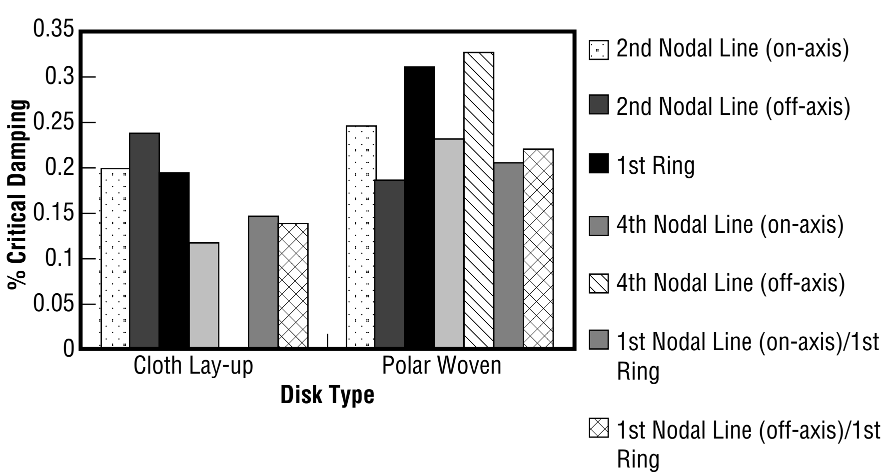

Figure 48.—Disk damping results.